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Effect of Steel Fiber Type on Compressive Strength and Modules of Rupture on Reactive Powder Concrete (RPC)

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Abstract: ***In concrete technology reactive powder concrete (RPC) is the latest investigation and its very important because Concrete alone was very weak in tensile strength and its ductility very limited and few resistance to cracking. Different types of fiber reinforced concrete are now used with plain concrete to produce high flexural strength, good performance in tensile strength, and high modulus of rupture and few in cracking appeared. In the present may researches appears to study the properties of steel fiber in reinforced concrete like flexure strength , tensile strength and compressive strength. In this study use reactive powder concrete with two type of steel fiber (end hook and micro), and investigate compressive strength, modules of rapture and cracks appear by used cube (100*100*100) mm and prism (385*75*75) mm. And used steel fiber range of (0 and 1%) from total volume of concrete. From test results steel fibers significant increase ductility and strength.***

Keywords: effect of steel fiber on concrete, kind of steel fiber, reactive powder concrete

1. Introduction

In the construction concrete now is the first material its mostly used in building and construction material, because of it have high compressive strength and its easy to make different shape and dimensions by used concrete. The main impediment when used concrete is the brittleness and its increase with the concrete increase. Brittleness has very affects on its execution of the concrete. Depending on the many studies in concrete field that found concrete with the high strength can be accomplished by reduce the water /cement ratio (w/c).that happened without any bad effect on the properties of concrete and the other materials in concrete. So many researchers begin to study and examine to understand the basic design of high strength concrete. The high strength concrete can defined as the concrete having large durability and high strength and ductility. Other wise the plain concrete is defined as a brittle material and it have small value of strain capacity and the modulus of rapture was low. Reactive Powder Concrete (RPC) is a new found as materials have high compressive strength, may be reach to 200 MPa , (RPC) can give good workability to possess excellent static and dynamic strengths, good durability under severe conditions , and low shrinkage and cracking to removal the weak point of concrete many researches found increase in the mix design different type of steel fiber to the concrete to give it many properties such as ductility, high flexural strength, fracture toughness durability of concrete.

Reactive powder concrete with steel fiber is widely used in construction parts such as ground floor, beams slab, piles, foundation, pipe, column, manholes.

Reactive powder concrete (RPC) has gets great interesting in last years in the world due to its properties such as; high strength, high ductility, high durability, limited shrinkage, high resistance to corrosion and abrasion.

Compressive strength of concrete is very important parameter according to the current design criteria, it used when design reinforced concrete structure.

In our study; used reactive powder concrete (RPC) with two type of steel fiber (end hook and micro steel fibers) by 1% of concrete volume.

Compressive strength tests were carried out on cube (100x100x100mm) were range from (30 to 100) Mpa.

2. Literature Review

The effects of type of steel fiber on the static and dynamic strength of RCC beams using different type of steel fiber (straight, hooked and raddled) fibers and found that the use of all these type of fibers cause to increase the ultimate moments on the beam and decrease cracks width in it. [1]. Conducted experimental work study crack, flexural strength on reinforcement concrete by used hooked end steel fiber and straight end steel fiber greater than 1% found that steel fiber with hooked end give larger increase in properties when compared with the straight end steel fibers[2].

When used steel fiber with different percentage from 0.5% to 2.5%, that found an increase in flexural strength for the concrete from 29.2% to 119.69% when compared to ordinary concrete [3]. Steel fibers may change the distribution of cracks, in the concrete and develop performance of the concrete .the steel fibers distribution in reactive powder concrete (RPC) affects on the mechanical properties and enhance its [4].

When used materials like glass, asbestos and polypropylene, with the steel fiber in the fiber reinforced concrete their mechanical properties can be used at higher temperature than the other fibers. In this study found that good ductility and resistance effect by glass, steel and plastic fiber is more than

the asbestos [5]. The compressive strength and ultimate flexural strengths were increase with added steel fiber to ordinary concrete, and found that ultimate flexural strength and compressive strength of UHPC specimens without use steel fiber were 19 and 105 MPa at 90 days and with added fiber to concrete they reached to above 35 and 150 MPa. [6].

Silica fume have very important affects on the cohesion bond between the reactive powder concrete material and steel fibers in it, and it compressive strengths was increase about 60%. The optimum cohesion is reach when (RPC) content silica fumes about 20–30% [7].

When added different kind of fibers to concrete (glass fiber ,steel fiber) with deferent volume and length to the sample and study tensile strength, compressive strength and flexural strength were tested on the concrete sample, that found the tensile strength and flexural strength of reinforced samples were increased in three times more than the controlled samples without fibers. [8]

Studies [9, 10, 11, 12, and 13] found that RPC good effect resistance and energy absorption ability. The addition of 2% steel fibers with aspect ratio of 65 to the RPC mix improve the tensile strength of composite cementations materials, of steel fiber the increase in tension.

Study analysis method that use of steel fiber in concrete cause to increases the load carry and flexural strength and reduces the cracks width that appears in concrete. [15]

Objective of the Study

The main objectives of this study is examining the used of difference types of steel fiber in reactive powder concrete and there effect on compressive strength and modulus of rupture and cracks appears in concrete.

3. Experimental Work

Materials

Describe the materials that used in the experimental part and their properties of (RPC) should have properties such as: maximum fine aggregate size between 0.3 to 0.6 mm, no coarse aggregate, low water / cement ratio (less than 0.2), high cement content, pozzolanic materials such as silica fume be used, to have high flow ability Super plasticizer is used to increase the concrete ductility and used different type of steel.

1) Cement

The cement is used in casting all specimens is ordinary Portland Cement (OPC). The chemical and physical properties of the cement is complied with the (Iraqi specification No.5/1984).

2) Silica Fume

It used as mineral admixture for production of high performance concrete in concrete due to its physical properties and chemical properties, silica fume can have very high durable and large strength. Its uses begin to solve the environmental pollution problems, and have safer and economical construction. It have very large surface area which improves the workability, strength, cracks resistance, permeability and durability and improve the microstructure of the concrete matrix resulting in more stronger and durable concrete. Silica fume in concrete has both engineering potential and economic advantage. Properties of the used silica fume described in tables (1).

Table 1: Silica Fume properties

Form	Viscous liquid
Color	Light yellow
Freezing point	-3 @ 25 °C
Specific gravity	1.05 ± 0.02 @ 25 °C
Dosage	0.5-2.5 L/100Kg of cementations materials
Air entrainment	Typically less than 2% additional air is entrained above control mix at normal dosages

3) Super plasticizer (SP)

Super Plasticizer is as a part of cement, it used to reduce the water bond proportion and improve workability and it Prevent segregation of particles and to improve the flow ability of concrete materials, its addition to concrete allows to reduce the water to cement ratio without any effect on workability of the mixture, and achieve high homogeneity to produce high performance concrete and the self-compacting concrete. Thus, it improves the total performance of the hardening fresh concrete; hyperplast PC200, which is a super plasticizing admixture, based on polycarboxylic ether polymers with long chains is used. The typical properties of hyperplast PC200 (according to the manufacturer editions) are shown in table (3). Hyperplast PC200 can be used with all Portland and cement replacement materials (Don Construction Products). The dosage that used in this work was 6 L/375 kg of cementations materials.

Table 2: Super plasticizer (SP) properties

Property	Result
Specific gravity	2.016
Fineness (blaine)	1600 kg/m²
Physical form	Powder
color	grey

4) Steel Fiber

Steel fibers can be classified in to the several types depend on there tensile strength, shape, dimensions (length, cross section), and aspect ratio is (the length divided by diameter). When the aspect ratio is high we can get the better performance. Steel fiber enhances the rigidity, flexural quality, shear and it general bendable conduct of cement. They play important role in the reinforcing of concrete construction. How much steel fiber we can add to a concrete mix? It depended on the objectives of the construction, cost savings, increase joint spacing or structural improvement. Fiber-reinforced normal concrete are mostly used for floors and pavements, but can be considered for a wide range of construction parts (beams, slabs, pipes and column etc). In this work we used two types of steel fiber (hook end and Micro steel fiber)

Table 4: sieve analysis of fine aggregate

The Grading		
Sieve size (mm)	Percent Passing %	A. I.Q.S.45/1984: Limits Zone 1
9.5	100	100
4.75	91	90-100
2.36	73	60-95
1.18	53	30-70
0.60	32	15-34
0.30	11.0	5-20
0.15	1.2	0-10

Figure 1: End Hook steel fibers

Figure 2: Micro steel fibers

Table 5: Physical and Chemical Properties of fine aggregate

Form	Viscous liquid
Color	Light yellow
Freezing point	-3 @ 25 °C
Specific gravity	1.05 ± 0.02 @ 25 °C
Dosage	0.5-2.5 L/100Kg of cementations materials
Air entrainment	Typically less than 2% additional air is entrained above control mix at normal dosages

5) Mixing

In this work we mix the dry material (cement, sand and silica fume) firstly by hand mix and then put them in the mixture and adding the percentage of water and mix them for 5 minutes and then adding super plasticizer to the concrete and continue for mixing to 15-20 minutes, and then adding the percentage of steel fiber to the concrete and mix them by hand mix because its difficult to mix them by mixture.

(Water/cement) ratio = 0.25 and steel fiber=1%

Figure 3: Mixing process

Table 3: Properties of the different kind of steel fiber

Kind	Length (mm)	Diameter (mm)	Aspect ratio (L/d)	Tensile strength (Mpa)
Hook end	50	1	50	1100
micro	13	0.2	65	2850

6) Fine aggregate

Well-graded natural sand was used as a fine aggregate in all the mixing process. The grading is lied in (Zone No. 1) conformed to the (Iraqi specification No. 45/1984) as in table(4) physical and chemical properties are in table (5)

7) Casting

When mixing of (RPC) with steel fiber were finished we but them in the cubes and prisms and after on day but them in the water for 7, 14, 28 and 60 days and then tested there compressive strength and modulus of rupture and cracks appears. The cube dimensions are (100x100x100) mm and prism dimensions are (385x75x75) mm there used in testing

Figure 4: Casting process

4. Testing and Results

1) Compressive Strength

Compressive strength test was carried out according to the ASTM C116 on actual cubic (100x100x100) mm, using the NTINIUS OLESN) testing machine of (200000 Ib-909 kN) capacity that is shown in Figure (5) and table (6). Failure load has been recorded for each equivalent cube and the compressive strength was calculated for cubes with reactive powder concrete without steel fiber for 7, 14, 28and 60 days The specimens were cured in water for 7, 28& 60 days. For maintaining uniform curing all the specimens are cured in the same curing conditions., and the average of three cubes were taken for each age, and also compressive strength were calculated for cubes with reactive powder concrete with two type of steel fiber (End hook steel fiber and Micro steel fiber) with percentage of 1% for 7, 14, 28and 60 days and the average of three cubes were taken. Compressive strength of the cubes was calculated by dividing the failure load by the area to which the load is applied.

Table 6: Results of compressive strength test

Type	Compressive strength Mpa			
	7 day	14 day	28 day	60 day
Plain	30	35	42	59
Hooked	33	48	59	77
Micro	40	58	70	100

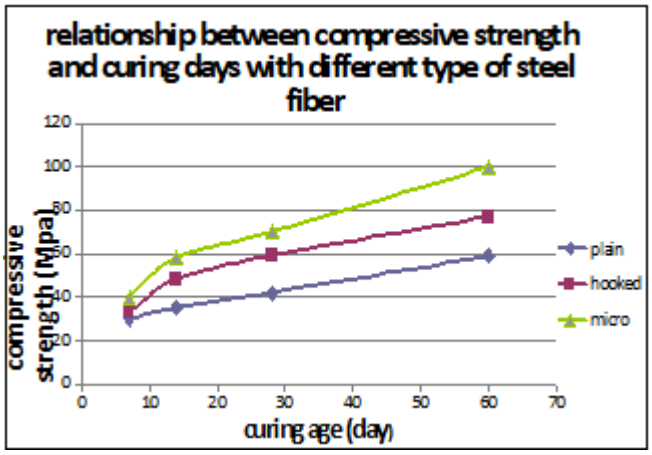

Figure 5: Compressive strength results

The results of the experiment work was appeared that an increase in the compressive strength of the reactive powder concrete (RPC) with adding steel fiber when compared with reactive powder concrete without adding steel fiber, and reactive powder concrete with the micro steel fiber give compressive strength more than hooked end steel with increase time of curing .

2) Flexural Strength

Modulus of rupture was tested by prisms with dimension of (75x 75x385) mm. Test was carried out according to ASTM C293 (2006).

The prisms with reactive powder concrete without steel fiber were tested with the age of 7, 28, and 60 days and the verge of three prisms was taken for all the age tested.

And test prisms with reactive powder concrete with 1% hook end steel fibers were tested with the age of 7, 28, and 60 days and the average of three prisms were taken for all the age tested.

And also prisms with reactive powder concrete with 1% micro steel fibers were tested at the age of 7, 28, and 60 days. And the average of three prisms was taken for all the age tested. As shown in figure (6) and table(7).

When tested the prisms we put the load in two points on them (two point load).

The flexural strength (modulus of rupture) is calculated using the formula.

$M.O.R = 3PL /2BD^2$

L=385 mm

B, D =75 mm

P: force failure in N

Table 7: Results of flexural strength test

Type	Flexural Strength Mpa		
	7 day	28 day	60 day
Plain	7.5	8.3	8.7
Hooked	10.4	13	15
Micro	10.8	14.5	15.8

The result appears increase in the flexural strength of reactive powder concrete (RPC) with using steel fiber when compared it without using steel fiber, and the micro steel fiber give more strength when compared with end hook steel fiber with curing age.

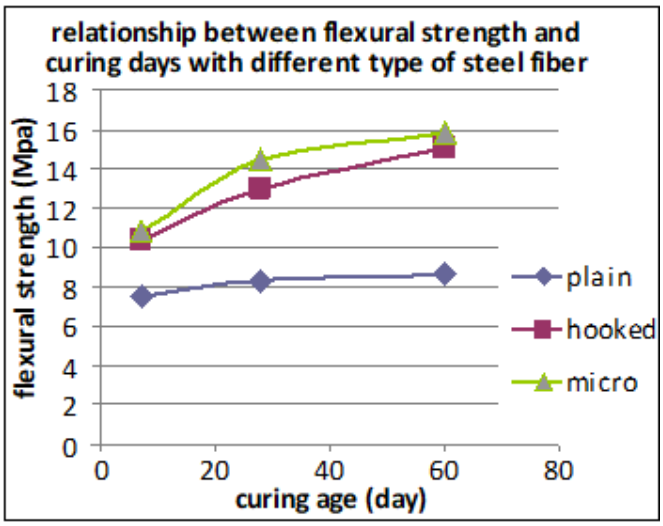

Figure 6: Flexural strength results

5. Discussion

1) Compressive strength test

Compressive strength for reactive powder concrete was increase when used steel fiber especially with micro steel fiber as seen in the table (6) and figure (5), the use of steel fiber in concrete with percentage of 1% the compressive strength was increase:

@ 7days 10%for hooked and 33% for micro
And @ 14 days 37% for hooked and 46% for micro
And @28 days 40% for hooked and 65% for micro
And @60 days 33% for hooked and 70% for micro
And can see mode of failure for the reactive powder concrete with steel fiber (hook end and micro) and without use steel fiber.

Figure 7: Mode of failure for reactive powder concrete without steel fiber.

Figure 8: Mode of failure for reactive powder concrete with end hooks steel fibers.

Figure 9: Mode of failure in compression of (RPC) with micro steel fibers

2) Flexural Strength Test

Test results indicated that the flexural strength (modulus of rupture) of reactive powder concrete with steel fiber increase with time of curing due to the reactivity of silica fume which started to develop strength with hydration slowly and give good compatibility with steel fibers ,as shown in table (7) and figure (6),when use of steel fiber in reactive powder concrete was increase flexural strength @ 7days 38.6% for hooked and 44% for micro.
And @ 28 days flexural strength was increase 56.6% for hooked and 74.7% for micro.
And @ 60 days flexural strength was increase 72.4% for hooked and 81.6% for micro.
Form result we can see the large increase of flexural strength of concrete with steel fiber because steel fiber carry tension

Figure 10: Mode of failure in reactive powder concrete hook end steel fiber for prism.

Figure 11: Mode of failure in (RCP) for prism.

Figure 12: Mode of failure for prism for (RPC)

3) Cracks appear in the concrete

Form testing results we found that reactive powder concrete without steel fiber when applied load and reach to failure load they fail and damage suddenly and we see a large cracks on them .And when compared that with reactive powder concrete with steel fiber gradually damaged happened and cracks appeared smaller specially in reactive powder concrete with micro steel fiber because the good bonds between concrete and micro steel fiber as shown in figure (13).

Figure 13: Mode of failure in (RPC) cube with micro steel fiber

6. Conclusion

The aim of this study was to assess the laboratory behavior of reactive powder concrete with different type of steel fiber in this study, the following conclusions are made:

1) Compressive strength and flexural strength of (RPC) were increases with increase curing time with all type of steel fiber
2) Compresssive strength of (RPC) was increase when used steel fiber special with micro steel fiber.
3) Mudulus of rupture of (RPC) was increase specially when used micro steel fiber.
4) Suddenly failure of reactive powder concrete without steel fiber (RPC) was happened.
5) Cracks appears was very small in (RPC) with micro steel fiber when compared with the anther type steel fiber

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